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DOI:
10.1111/ggi.13220

Document Version
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Link to publication record in King's Research Portal

Citation for published version (APA):
Lee, S., & Sabbah, W. (2018). Association between number of teeth, use of dentures and musculoskeletal frailty among older adults. *Geriatrics & gerontology international*, *18*(4), 592-598. https://doi.org/10.1111/ggi.13220

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Download date: 04. May. 2023

Association between number of teeth, use of denture and musculoskeletal frailty among older adults

Seoyoung Lee; Wael Sabbah

King's College London Dental Institute at Guy's, King's College and St. Thomas' Hospitals. Bessemer Road, Denmark Hill, London, SE5 9RS, United Kingdom

Corresponding author:

Wael Sabbah, King's College London Dental Institute at Guy's, King's College and St. Thomas' Hospitals. Bessemer Road, Denmark Hill, London, SE5 9RS, United Kingdom

Telephone number: 020 3299 3272 E-mail: Wael.sabbah@kcl.ac.uk

Short title: Dental status and frailty

ABSTRACT

Aim: To assess whether there is a relationship between musculoskeletal frailty and number of teeth/ denture use, and whether nutritional intake explains this relationship, in a sample of older American.

Methods: Data from the National Health and Nutrition Examination Survey 2011/2012 were used. Handgrip strength was used to indicate musculoskeletal frailty. Number of teeth and denture use were examined by calibrated dentists. Information on socio-demographic factors, nutrients intake and general health status were collected through interviews. Logistic regression models were used to assess the association between number of teeth/denture use by participants having less than 20 teeth and musculoskeletal frailty. Poisson regression analyses were used to assess the association between number of teeth/denture use and nutritional intake.

Results: There was no statistically significant difference in musculoskeletal frailty between denture user with >20 teeth and those with ≥20 teeth. Non-denture user with >20 teeth had higher odds for musculoskeletal frailty (OR:1.32, 95%CI:1.04,1.68). Accounting for nutritional intake explained more than 30% of this relationship. Having fewer teeth was associated with deficiency of nutritional intake regardless of use of denture.

Conclusion: Denture use is associated with lower chances of musculoskeletal frailty among older Americans. Nutritional intake explained around one third of the association, but most of the relationship was attributed to comorbidity. The findings imply that dental status might play a role in musculoskeletal frailty.

Key words: aging, dentures, hand strength, nutritional intake, tooth loss.

INTRODUCTION

Frailty is a multidimensional medical syndrome marked by declines of musculoskeletal function, reduced functional reserve capacity and cumulative vulnerability against minor stressors. These could consequently prompt risk of adverse health-related outcomes such as disability, cognitive disorders, institutionalization and mortality (1,2). Frail musculoskeletal system has been regarded as one of the important indicators of frailty (3). Handgrip strength is a major parameter of physical performance which has been repeatedly used to diagnose musculoskeletal frailty (4,5).

Several factors are implicated in musculoskeletal frailty including older age, long standing illness, smoking, excessive alcohol consumption, lack of physical activities (1), and inadequate intake of essential nutrients (6). Limited masticatory function is another potential and modifiable risk factor for musculoskeletal frailty which possibly operates through an impact on micronutrients (7,8). Earlier studies have shown that malnourishment could be relatively improved when masticatory functions are recovered by denture restorations (9). Unsurprisingly, recent studies have examined the relationship between oral health status namely, periodontal disease, and number of teeth, and found an association with general frailty (8,10), and between need for dentures and general frailty (11). Fewer studies have focused solely on musculoskeletal frailty and oral health. There were also little efforts to explain the underpinning causes of the relationship between frailty and oral health, particularly number of teeth and use of denture (10,11). One of the plausible pathways for this association is nutritional intake. Given the gap in the literatures, we set out to examine the association between musculoskeletal frailty and dental status indicated by number of teeth/denture use, and whether this association, if existed, is mediated by nutritional intake in a nationally representative sample of American aged 50 years and older.

METHODS

We used data from the National Health and Nutrition Examination Survey (NHANES) 2011-2012, a cross-sectional nationally representative survey of non-institutionalized Americans. Overall, 9,338 out of 13,431 selected persons completed the interview and examination, details of the survey are accessible elsewhere (12).

Initially we included 2,704 participants aged 50 years and older. The cut-off point of 50 years was selected to allow greater variations in number of teeth. This age is also used as a cut-off point for other surveys of older adults (13). The final analysis included 1,852 (924 males and 928 females, mean age 62.9 years) who had complete data on musculoskeletal frailty and other explanatory factors used in the analysis.

NHANES 2011-2012 comprised interviews administrated by trained interviewers in participants' households. Clinical examinations including handgrip strength, BMI and oral health assessment were conducted in Mobile Examination Centre (MEC). Examiners completed particular training and were monitored throughout the survey (14).

Outcome variables

Musculoskeletal frailty was calculated from maximum grip strength measured by an isometric grip strength test using a handgrip dynamometer (Takei Digital Grip Strength Dynamometer, Model T.K.K.5401). Participants were asked to squeeze the appliance as hard as possible in uprightly standing posture. Maximum handgrip strength was measured on each side, three times separated by 60 seconds and alternating hands. The highest value, which is less likely to be influenced by the number of trials rather than mean (15) was yielded to the ultimate handgrip strength. Considering the age group of the sample, a relatively higher cut-off point for handgrip strength was selected to indicate whether participants had musculoskeletal frailty. The cut-off points were 20kg for women and 30kg for men, which were within the range for borderline musculoskeletal frailty in a number of reviews (5,15,16).

We also used lower cut-off points for weak grip strength of 26kg for men and 16kg for women (5), and the continuous variable (17) for grip strength in a sensitivity analysis with dental status.

Explanatory variables

Status of the denture and tooth count was assessed by dentists at the MEC. Other studies have shown that having at least twenty teeth is essential for adequate masticatory function (9,18). Participants were categorised into three groups: having at least 20 teeth, denture-wearer with >20 teeth, and non-denture-wearer with >20 teeth.

Nutritional intake was based on data from 24-hour dietary recall interview, which were conducted firstly through MEC in-person then by telephone 3-10 days later. Inadequate intake of nutrients related to frailty (19) was calculated according to the values of Recommended Dietary Intakes produced by US food and drug administration (2). The following cut-off points for the respective 13 nutrients were used: protein (men,<56g/d; women,<46g/d), Vitamin D (both 50-70yrs, 15µg/d; both>70yrs, 20µg/d), calcium (men>50yrs and≤70yrs, 1000mg/d; men>70yrs, 1200mg/d; women50yrs, 1000mg/d; women>50yrs, 1200mg/d), Vitamin A (men, 900µg/d; women, 700µg/d), Vitamin E (both, 15mg/d), Vitamin B_{12} (both <2.4µg/d), Vitamin B_6 (both50yrs, 1.3g/d; men>50yrs, <1.7g/d; women>50yrs, <1.5g/d), Vitamin C (men, 90mg/d; women, 75mg/d), folate (both, <400µg/d), zinc (men,<11mg/d; women, <8mg/d), polyunsaturated fatty acids (men, 160mg; women, 90mg), ß-carotene (both, 3mg), and dietary fibre (men 50yrs, 38g/d; men >50yrs, 30g/d; women 50yrs, 25g/d; women >50yrs, 21g/d). A combined nutritional intake variable was created by summing up the aforementioned 13 nutrients intake variables (ranging from ‘0’ adequate consumption of 13 nutrients to ‘13’ inadequate consumption of 13 nutrients).

Covariates

Demographic factors included age (≥50years), gender, race/ethnicity (Hispanics 'Mexican American and other Hispanics', Non-Hispanic Blacks, Non-Hispanic Whites, and others). Marital status was categorized to 'singles' including widowed, divorced, separated and never married versus 'couples'. Family income ratio to poverty (ratio of family income to poverty threshold) indicated income. Education was recoded into four groups: <high school, high school, college and >college education. Self-reported physical activity was dichotomised as 'active'(at least 150 minutes for moderate intensity exercise or equivalent other intensity exercises) and 'inactive', less than the recommendation of the Physical Activity Guidelines for Americans released by the U.S. Department of HHS (20). Smoking was categorised into 3 groups: current smoker, never smoker (smoked less than 100 cigarettes in lifetime), and former smoker (12). Systemic health conditions were self-reported doctor diagnosis of chronic conditions including hypertension, cardiovascular diseases, stroke, arthritis, and cancer. A variable was created to indicate whether a participant had any systemic condition or not. Diabetes was used as a separate variable given its relationship with tooth loss. Body Mass Index (BMI) was categorised into four groups: underweight "<18.5", normal weight ">18.5 to <25", overweight ">25 to <30" and obese "30 and over" according to CDC definition (21). In the regression analysis, due to a small number in the underweight group, underweight and normal weight were combined.

Statistical analysis

Data were analysed using survey command in STATA. First, we examined the distribution of all the variables included in the analysis and the percentage of individuals with musculoskeletal frailty.

A set of logistic regression models was used to examine the association between musculoskeletal frailty and dental status (≥20 teeth, <20 teeth who use denture, <20 and no

denture), and the mediating role of nutrition. To assess the contribution of nutritional intake in the association between dental status and musculoskeletal frailty, first we examined the relationship between dental status and frailty adjusting for age and gender, then we introduced the variable for nutritional intake in the next model. We calculated percent reduction in the odds ratios between dental status and frailty using the formula: Percent reduction in OR= $OR_{\text{dental status adjusting for age and gender}} - OR_{\text{dental status additional adjusting for nutrition}} / OR_{\text{dental status adjusting for age and gender}} - 1) X 100$ (14). This difference is sometimes interpreted as the indirect effect (22). The rest of the covariates were introduced in the final mode to assess their respective contribution to musculoskeletal frailty.

We used Poisson regression to demonstrate the relationship between nutrients intake and dental status. Finally, sensitivity analyses were conducted to assess the relationship between dental status and hand grip using a lower cut-off point of grip strength (5) and the continuous variables of grip strength (17).

RESULTS

The main characteristics of 1,852 participants and the percentage of frail individuals are reported in Table 1. The percentage of participants with musculoskeletal frailty was 9.1%. Total mean number of teeth was 20.5, and 16.4 within frail participants. Overall, 71.5% of the participants had 20 teeth and more, 9.6% had less than 20 teeth but used dentures (Table 1).

In the unadjusted analysis those with <20 teeth and did not use denture were significantly less likely to be frail than those with ≥20 teeth with odds ratio 2.94 (95%CI: 2.30, 3.77). Those <20 teeth but used denture did not have statistically significant odds for frailty (OR1.24, 95%CI: 0.64, 2.37).

In the regression model adjusting for gender and age (Table 2), individuals who had >20 teeth and did not use denture were significantly more likely to have musculoskeletal frailty than those with 20 teeth or more, odds ratio 1.32 (95% CI:1.04,1.68). After adjustment for nutritional intake, this odds ratio was attenuated to 1.22 and lost statistical significance. It is worth noting that these two odds ratios are sometimes referred to as total and direct (effect), respectively (22). The percentage reduction in the odds ratio (indirect effect) for association between non-use of denture and musculoskeletal frailty after accounting for nutrition was 31%. There was no statistically significant difference between those who had <20 teeth but used denture and those who had ≥20 teeth (Table 2). Poor nutritional intake, marital status (single) and lack of physical activities were all significantly associated with musculoskeletal frailty, while being overweight or obese had lower odds for frailty (Table 2).

When we examined the relationship between nutritional intake and number of teeth/use of denture, those who had <20 teeth and did not use denture, and those who used denture had higher rates of deficiency nutrients intake than those with ≥20 teeth with prevalence rate 1.20 (95% CI:1.13,1.28) and 1.15 (95% CI:1.07,1.23), respectively in a

model adjusting for age and gender. Finally, having <20 teeth and not using a denture was significantly associated with a lower cut-off point of grip strength, OR 3.54 (95%CI: 1.92, 6.49) and with the continuous variable of grip strength with regression coefficient of -3.55 (95% CI -4.75, -2.35).

DISCUSSION

This study examined the association among number of teeth and denture use by older adults and musculoskeletal frailty among US community-dwelling adults aged 50 years and older, and assessed the role of adequate intake of nutrients in this relationship. The main findings suggest that nutrients intakes mediate the observed relationship between non-use of denture by those with less than 20 teeth and musculoskeletal frailty. Accounting for key nutrients intake relevant to musculoskeletal frailty explained almost one third of the association between non-use of denture by those with less than 20 teeth and musculoskeletal frailty, thus indicating a mediating role of nutrition in this relationship. Furthermore, those who had less than 20 teeth were more likely to have inadequate nutritional intake whether using denture or not. The findings of this study of a nationally representative sample of USA older adults, to some extent supported the study hypothesis that nutritional intake mediates the relationship between dental status and musculoskeletal frailty indicated by grip strengths. Other risk factors explained most of the relationship between dental status and frailty.

Few studies have examined the relationship between oral health, particularly periodontal diseases, number of teeth and general frailty (8,23). Others have also argued that older adults who need dentures were more likely to be frail (11). However, there were little attempts to explain the underpinning causes of the relationship. The current study has similarly shown a relation between dental status and musculoskeletal frailty using a nationally representative sample of US adults that included slightly younger groups and has demonstrated a mediating role for nutrients intake.

Earlier studies have suggested that adequate intake of micronutrients such as vitamins, minerals, protein and energy plays an important role in musculoskeletal frailty. Others have argued that chewing inability, mainly resulting from inadequate dentition negatively impacts nutritional intake (19,24). The findings of the current analysis are generally in line with these

studies. Furthermore, there was no statistically significant difference in musculoskeletal frailty between denture users with less than 20 teeth and those with 20 teeth or more which implies a possible role for use of dentures in musculoskeletal frailty among older adults.

One of the important findings of the current study is the significant relationship between inadequate dentition and deficiency in intake of essential nutrients, regardless of the use of denture, a consistent finding with earlier research (25)(26). These findings highlight the importance of having adequate dentition to maintain chewing ability and subsequently adequate nutrients intake from various foods. In addition, the strong relationship between nutritional intake and frailty suggests that adequate intake of essential nutrients to maintain muscle mass and strength is important to prevent musculoskeletal frailty. This finding is also consistent with previous studies that demonstrated a significant role of inadequate nutrients intake and general frailty (27).

In the current study, the association between dental status, indicated by number of teeth/ denture use with frailty was further attenuated after adjusting for socioeconomic position and other risk factors for frailty. Although nutrition intake explained around 30% of this relationship, more than 90% of the relationship was explained away by other socioeconomic, behavioural factors and systemic conditions. This finding suggests additional unexplored contributors to the relationship between dental status and musculoskeletal frailty. It is possible that most of the relationship is a result of common predisposing conditions such as diabetes, or risk behaviours like smoking. Socioeconomic conditions could also be one of the underpinning determinants of both frailty and dental status that explain this relationship (28). Other factors not included in the analysis such as genetic susceptibility could have also contributed to the relationship.

One of the important findings of this study is that using a denture by those who had less than 20 teeth appeared to play an important role in musculoskeletal frailty, which was in

line with an earlier study on frailty and use of dentures (11). On the other hand, participants with less than 20 teeth who used dentures had higher odds of inadequate nutritional intake than those with adequate dentition. Although not tested in the study, these findings could be attributed to inability to eat specific food items or to the condition of the dentures. Although prostheses improve masticatory function, bite force of dentures is much weaker than that of natural dentition. The findings pertaining to the relationship between denture use and malnutrition is also consistent with previous studies that demonstrated that denture users who had difficulties in chewing or reported using ill-fitting denture were more likely to be malnourished (29).

Aside from other socioeconomic and behavioural factors discussed earlier, it is also possible that the impact of replacing teeth on the patients' quality of life could have attributed to this relationship. In other words, use of denture could help older adults to overcome speaking problems, improve appearance, and thus achieve self-esteem, or self-confidence (30). These advantages could encourage older adults to be involved in social interaction and physical activities, which are important contributors to frailty (30).

To the best of our knowledge, this is the first study that the possible role of nutrition in the relationship between number of teeth/denture use and musculoskeletal frailty in a nationally representative sample of older Americans. However, the study has few limitations. The cross-sectional nature of the survey does not allow conclusion about temporality. The lack of information on the locations, types or fits of dentures were not examined which could affect masticatory function. Moreover, the exclusion of institutionalised individuals could have led to exclusion of many participants who potentially had higher rates of musculoskeletal frailty. The use of a composite indicator of nutrients related to frailty could also be seen as a limitation as they might different impact on frailty; however it was not possible to include each of them separately in the regression analysis and the aggregate

variable was only used to demonstrate a possible role of nutrients in general in the relationship. Furthermore, the use of food diary does not necessarily reflect actual nutrition status.

To date, the majority of efforts for improving frailty were focused on nutrition strategies including health education, whilst the influence of teeth on the dietary restraint of the elderly has been neglected. The findings of this analysis along with that reported in earlier research (11,23) suggest that use of denture could be a neglected intervention that could potentially have a preventive impact on musculoskeletal frailty. These findings also highlight the importance of restoring dentition and developing oral health policies to ensure older adults maintain functional dentition throughout their life. Interventional studies should be carried out to confirm or refute the apparent relationship among denture use, nutritional intake, and frailty. Research is also needed to build interventions that could contribute to dental and nutritional intake simultaneously.

This study demonstrated that nutrient intake mediated the relationship between musculoskeletal frailty and having less than 20 teeth and not using denture. The findings suggest that restoring functional dentition by use of denture could be a neglected factor that might halt musculoskeletal frailty among older people.

Acknowledgements

None

Disclosure Statement

This study did not receive any financial support.

The authors declare no conflict of interest.

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Table 1. Distribution of main variables used in the analysis – (N=1852), National Health and Nutrition Examination Survey 2011-2012, United States

		Overall percentage/ mean (95% CI)	Percentage / mean (95% CI)	
			Frail	Non-frail
Gender	Male	47.6 (45.5, 49.7)	35.9 (24.9, 48.7)	48.8 (46.3, 51.2)
	Female	52.4 (50.3, 54.5)	64.1 (51.3, 75.1))	51.2 (48.8, 53.7)
Age in years (mean)		62.9 (62.2,63.7)	72.7 (71.8, 73.6)	62.0 (61.3, 62.7)
Ethnicity	Non-Hispanic White	77.7 (70.6, 83.5)	74.9 (63.9, 83.3)	78.0 (70.8, 83.9)
	Hispanic American	7.5 (5.0, 11.4)	10.9 (6.8, 17.1)	7.2 (4.6, 11.2)
	Other Races	5.5 (3.7, 7.9)	7.1 (3.4, 14.0)	5.3 (3.5, 8.0)
	Non-Hispanic Black	9.3 (5.7, 14.6)	7.1 (3.9, 12.6)	9.5 (5.9, 15.0)
Poverty-income ratio (mean)		3.18 (2.93, 3.43)	2.5 (2.3, 2.8)	3.2 (2.9, 3.5)
Education	Above college	31.8 (35.6, 38.7)	18.5 (12.1, 27.3)	33.1 (26.6, 40.3)
	College	30.2 (25.9, 34.9)	23.7 (16.0, 33.5)	30.8 (26.1, 36.0)
	High school	21.6 (17.3, 26.5)	29.6 (23.4, 36.6)	20.8 (16.4, 25.9)
	Grade school or Less	16.5 (12.7, 21.2)	28.3 (19.9, 38.4)	15.3 (11.4, 20.4)
Marital status	Married/ couple	65.1 (60.3, 69.7)	53.2 (43.0, 63.2)	66.2 (61.4, 70.9)
	Single	34.9 (30.4, 39.7)	46.8 (36.8, 57.0)	33.7 (29.2, 38.6)
Smoking status	Never smoker	48.5 (44.9, 52.2)	57.9 (47.5, 67.7)	47.6 (43.3, 51.9)
	Former smoker	34.8 (31.3, 38.5)	33.3 (21.1, 48.2)	34.9 (31.0, 39.1)
	Current smoker	16.7 (14.6, 19.1)	8.8 (3.8, 19.1)	17.5 (15.3, 19.9)
Diabetes	Non-diabetic	83.2 (80.4,85.6)	70.0 (60.5, 78.0)	84.5 (81.3, 87.2)
	diabetic	16.8% (14.4, 19.6)	30.0 (22.0, 39.5)	15.5 (12.8, 18.7)
Chronic conditions	No	29.5 (26.2, 33.2)	13.7 (9.0, 20.4)	31.1 (27.5, 35.1)
	Yes	70.5 (66.8, 73.8)	86.3 (79.7, 91.0)	68.9 (65.0, 72.6)
Body Mass Index	Underweight (<18.5kg/m^2)	0.9 (0.5, 1.9)	6.2 (1.7, 20.5)	0.4 (0.2, 0.7)
	Normal range (18.5-24.95kg/m^2)	24.9 (22.0, 28.0)	31.0 (23.8, 39.2)	24.3 (21.2, 27.6)
	Overweight (25-29.95kg/m^2)	35.5(32.6, 38.6)	32.2 (24.3, 41.3)	35.9 (32.4, 39.5)
	Obese (≥305kg/m^2)	38.7 (33.7, 43.9)	30.5 (23.4, 38.7)	39.5 (34.5, 44.7)
Physical activity	Active	63.9 (59.4, 68.1)	37.9 (29.6, 47.0)	66.5 (61.4, 71.2)
	Inactive	36.1 (31.9, 40.6)	62.1 (53.0, 70.4)	33.5 (28.8, 38.7)
Dental status	20 and more than 20 teeth	71.5 (67.0, 75.6)	54.0 (48.3, 59.7)	73.2 (68.3, 77.6)
	Less than 20 teeth with denture	9.6 (6.9, 13.1)	8.8 (5.6, 13.5)	9.6 (6.7, 13.7)

	Less than 20 teeth without denture	18.9 (16.7, 21.4)	37.2 (31.5, 43.3)	17.1 (14.8, 19.7)
Nutrition status (higher value indicates poorer nutrition) (mean)		7.4 (7.1, 7.8)	8.4 (7.9, 9.0)	7.3 (7.0, 7.7)

Table 2. Logistic regression showing odds ratios (95% CI) for factors associated with musculoskeletal Frailty among older Americans aged 50 and older

Variable		Model 1	Model 2	Model 3
		Odds Ratios (95% CI)		
Dental status (Reference: ≥20 teeth)	<20 teeth, use denture	1.16 (0.61, 2.17)	1.04 (0.59, 1.86)	0.69 (0.35, 1.39)
	<20 teeth, no denture	1.32*** (1.04, 1.68)	1.22 (0.96, 1.55)	1.02 (0.73, 1.42)
Age		1.14*** (1.11, 1.16)	1.13*** (1.11, 1.16)	1.11*** (1.08, 1.15)
Gender (females)		1.56 (0.84, 2.86)	1.51 (0.80, 2.86)	1.13 (0.56, 2.27)
Poor Nutritional intake			1.11* (1.02, 1.21)	1.09* (1.01, 1.17)
Ethnicity (Reference: Non-Hispanic White)	Hispanic American			1.97 (0.90, 4.31)
	Non-Hispanic Black			0.64 (0.39, 1.03)
	Other Races			1.58 (0.62, 4.02)
Poverty income ratio				0.97 (0.82, 1.13)
Education (Reference: >college)	College			0.97 (0.42, 2.28)
	High school			1.64 (0.81, 3.29)
	Less high school			1.28 (0.65, 2.52)
Marital status (single)				1.47* (1.04, 2.09)
Smoking (reference never)	Former smoker			0.67 (0.34, 1.32)
	Current smoker			0.46 (0.17, 1.26)
Diabetic				2.07* (1.07, 4.01)
Chronic diseases				1.43 (0.84, 2.43)
BMI (Reference: <25kg/m^2)	Overweight (25-29.95kg/m^2)			0.49* (0.24, 0.99)
	Obesity (≥30kg/m^2)			0.36** (0.21, 0.62)
No physical activity				2.30** (1.52, 3.48)

*** *p<0.001*, * *p<0.05*